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SELF-INSTRUCTIONAL SUPPLEMENTS FOR A TELEVISED PHYSICS COURSE, STUDY PLAN AND EXPERIMENTAL DESIGN.

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THE INITIAL PHASES OF A STUDY OF SELF-INSTRUCTIONAL AIDS FOR A TELEVISED PHYSICS COURSE WERE DESCRIBED. THE APPROACH, EXPERIMENTAL DESIGN, PROCEDURE, AND TECHNICAL ASPECTS OF THE STUDY PLAN WERE INCLUDED. THE MATERIALS WERE PREPARED TO SUPPLEMENT THE SECOND SEMESTER OF HIGH SCHOOL PHYSICS. THE MATERIAL COVERED STATIC AND CURRENT ELECTRICITY, ELECTRIC FIELDS AND MOTORS, REFLECTION AND REFRACTION OF LIGHT. THE MATERIALS WERE ORGANIZED TO CORRESPOND TO A PHYSICS SERIES BEING TELECAST DAILY BY TWO EDUCATIONAL TELEVISION STATIONS IN PITTSBURGH. ALSO INCLUDED WERE DISCUSSIONS OF (1) THE SELECTION OF METHODS OF PRESENTATION, (2) THE DESIGN OF AN EXPERIMENT, (3) THE CONDUCT OF AN EXPERIMENT, AND (4) METHODS OF EVALUATION. THE STUDY WAS EXPECTED TO CONTRIBUTE TO THE VALUE OF FUTURE APPLICATIONS AND RESEARCH BY USING LARGE GROUPS OF STUDENTS AND EXTENSIVE BLOCKS OF MATERIALS. RELATED REPORTS ARE ED 003 205 THROUGH ED 003 207, ED 003 214, ED 003 215, AND ED 003 655 THROUGH ED 003 659. (RS)

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SELF-INSTRUCTIONAL SUPPLEMENTS

FOR A

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STUDY PLAN AND EXPERIMENTAL DESIGN

AMERICAN INSTITUTE FOR RESEARCH
Pittsburgh, Pennsylvania

SELF-INSTRUCTIONAL SUPPLEMENTS FOR A TELEVISED PHYSICS COURSE* — —

Final Report

Study Plan and Experimental Design

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American Institute for Research

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ABSTRACT

This report describes the initial phases of a study being conducted by The American Institute for Research on the use of self-instructional supplements for a televised physics course. Details of the approach, the experimental design, and the procedure are described, and several technical aspects of the study plan are discussed.

The object of the study is to determine the effectiveness of recently developed self-instructional techniques in a representative situation. This will be done by determining the relative achievement of high-school students furnished with specially developed tutorial materials compared to that of students not furnished with additional materials or furnished with traditional study guides or workbooks.

The self-instructional materials now being developed by the project staff are based on promising preliminary findings on the advantages of guiding the learning of complex subject-matter by means of small, carefully arranged steps. Each step consists of a question, to which the student must actively respond using his own words, and an answer against which the student can evaluate his response. By experiencing frequent and regular reward for making correct responses, the student is likely to learn difficult concepts more rapidly and retain his newly acquired knowledge for a longer period of time than he would otherwise have done.

These materials are being prepared to assist students with a large portion of the second semester of their high-school course in physics. Programs, as the sequence of steps are called, are being written on static and current electricity, electric fields and motors, reflection of light, and refraction of light. In addition, it is intended that some supplementary materials will be developed to accompany the course units on electronics and atomics. For purposes of this study it is necessary to have consistency in course content and, at the same time, permit a realistic degree of variability in student aptitude, textbooks used, and classroom methods. To achieve these conditions, the materials are being organized to correspond to the Encylopedia Britanica Harvey E. White physics series being telecast daily by Pittsburgh Educational Television Stations WQED and WQEX. Only classes regularly watching this series will participate in the study.

The achievement measures which will be used are being prepared by Educational Testing Service especially for this study. One hour-long examination will be administered to all participating students for each unit in the course. A standard College Entrance Examination Board physics achievement test and a brief attitude questionnaire will also be administered near the end of the school year. The test results will be used to determine the general effectiveness of the kinds of self-instructional materials being prepared and to evaluate several variations in the use of the materials.

An appendix to the report discusses a number of technical considerations of current interest to researchers working with programmed, self-instructional materials. This section describes the specific features of the programs being developed for this study and discusses several alternative methods for individually presenting programs to students.

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INTRODUCTION

There is, at present, a large amount of interest in the development of efficient and economical methods for introducing technical devices to assist in many aspects of classroom instruction. As suggested by Ramo (1959) and others, our present ability to reproduce rather complex human skills by mechanical means can lead to great strides in educational practices. A growing concern over the magnitude of current and future responsibilities of our educational system has focussed on the need to provide an increasingly thorough education to rapidly increasing numbers of students. Reluctantly, it has been necessary to spread the supply of trained teachers thinner and thinner to meet the needs of both expanding curricula and expanding populations. As the stresses on our school systems multiply, the danger that desirable standards of quality will begin to slip becomes more pronounced. Before this happens, better instructional methods must be developed to enhance the effectiveness of the supply of teachers that is and will be available. The use of automation to accomplish many teacher functions seems to be a very promising place to start toward this goal. The investigation described here is one step in this direction. It is designed to show the level of achievement attainable through the combined use of two forms of instructional assistance, the televised lecture and self-instructional materials.

The specific purpose of this research is to investigate the utilization of self-instructional materials as supplements to accompany a televised high school physics course. As one of the more versatile of the recently developed forms of educational media, television has been enthusiastically adopted as an aid in presenting a wide variety of topics and courses. It may be the case, however, that instruction by television alone will not consistantly produce the learning required for desired levels of attainment. Several studies, for example those reported by Hovland, Lumsdaine and Sheffield (1949), Maccoby and Sheffield (1958), and May and Lumsdaine (1958), have shown that active, overt responding by students is more effective for learning than passive exposure to the material. While television and films afford excellent means for the presentation of material, they cannot promote the interaction between student and teacher which both fosters superior attainment and provides the learner as well as the teacher with valuable information as to the progress being made.

Recent developments in another educational medium, that of self-instructional materials, suggest that this technique could prove quite valuable as a supplement to filmed or televised instruction. As described by Skinner (1954, 1958), Lumsdaine (1959b) and others, these materials permit each student active practice with the concepts being studied and, at the same time, provide effective guidance in the form of carefully sequenced steps. The complementary attributes of television and self-instructional media suggest that, in combination with each other, a considerable amount of the educational process can successfully be furthered by mechanical devices. Television, with its capability for presenting information, demonstrating applications, and motivating the student, is well suited as a tool for presentation to large numbers of students. This use of audio-visual assistance has been widely recognized and, for this reason, educational television has been widely adopted in the classroom. Self-instructional materials, on the other hand, are capable of promoting student practice and of assisting learning through simulating many of the techniques used by a teacher or tutor. Together, these media can duplicate considerable portions of the educational process.

Self-Instructional Materials

Although the classroom use of television or movies is now rather commonplace, the self-instruction or "teaching-machine" technique is not yet widely known as a factor in education. It seems likely, though, that the development of practical methods of self-instruction, based on the use of specially designed tutorial materials, will eventually be one of the most important contributions of psychological science to educational practice. Actually, many attempts have been made, at one time or another, to automate procedures for providing guided student practice. The critical features or principles involved in generating desirable levels of student attainment have not been satisfactorally understood until recently, however, when the results of a sufficiently large number of laboratory studies on learning have been available to develop concepts adequately describing the circumstances under which learning is most efficient. The more important of these concepts can be described as follows:

1. Active student response. Provision should be made for the student to respond overtly. It now seems reasonably clear that mere exposure to new material is not a very efficient means of promoting learning. Only when the

student has practiced the responses he is to learn can we be sure they have been firmly established in his repertoire.

2. Feedback to student. Provision must be made for informing the student as to the correctness or incorrectness of his responding. Such "feedback" or "reinforcement" should follow each occurance of a response, especially during early stages of training.

3. Promptness of feedback. Feedback which follows the response immediately tends to be much more effective than a long delay for promoting effective learning.

4. Use of small steps. Learning is substantially more efficient when completed in many small steps rather than a few big steps. This is especially important as the material to be learned increases in complexity.

5. Careful sequencing. Efficiency of learning is dependent, to a very marked degree, on the sequence of steps. They must be carefully ordered, both as to complexity and difficulty, for learning to proceed most smoothly.

6. Ample practice. Frequent repitition of responses rather than only one occurance is usually desirable for effective retention. Practice and review are increasingly important as the amount of material to be learned increases.

Researchers have recently begun to adapt these and related principles for use in individual self-instruction by converting them to rules for presenting material individually to students. The technique for preparing subject-matter content according to these principles has been called "programming." A "program" or a unit of sequenced materials generally consists of a series of questions and answers called "frames," each representing one small step in the learning process. A few illustrative frames are presented in Figure 1. These sample frames represent, of course, only a small segment of a program. They are very "easy" frames, similar to those which would occur early in a program and hence do not illustrate the degree of subject matter complexity which can be handled in this manner.

As can be seen from the sample which appears on the following two pages, a large number of frames is often required to provide adequate practice on even a simple task. All the information contained in the example could, of course, have been presented concisely in tabular fashion. However, it seems clear that the rules determining how adequately information can be presented for reference are very different from those that determine how adequately information will be learned by a student.

Problem: Teaching the Use of Metric Measures of Length

(Note: In actual practice, the answer or answers would be presented following each frame, and would not be visible to the student while he is making his responses. To achieve the same effect in this sample, the column of answers should be covered and each answer exposed only after the question has been read and a response made.)

QUESTIONS	ANSWERS
1. When we measure the length of something we see how many inches long it is or how many feet long it is. A pencil, for example, is about six _____ long and a log might be about ten _____ long.	inches feet
2. Inches and feet are what we call <u>units</u> of measure. To describe the length of an object, we say it is so many units long, as nine inches or seven feet. Yards and miles are also _____ of length.	units
3. Sometimes different people use different _____ of measure, depending on what they want to say. One person may say a stick is two feet long while another says it is _____ inches long.	units twenty-four
4. In the kind of units we have been talking about, twelve _____ are equal to one _____.	inches foot
5. Three feet or ____ inches equals one _____. There are 5280 feet in a _____.	36 yard mile

Figure 1

QUESTIONS	ANSWERS
6. Most scientists do not use inches, feet, yards, and miles as units of length. They use a unit called a **meter** which is 39.37 inches. Their unit, the _____ is a little longer than what we call a _____.	meter yard
7. A meter is 39.37 inches. To find the number of inches in <u>two</u> meters, we multiply _____ by 2, which gives us _____ inches. This is a little more than six and a half _____.	39.37 78.74 feet
8. A line one meter long is _____ inches long. One <u>tenth</u> of a meter is _____ inches long. One tenth of a meter is called a decimeter.	39.37 3.937
9. Since a meter is _____ inches, one tenth of a meter, or a _____ is about four inches.	39.37 decimeter
10. One hundredth of a meter is called a <u>centimeter</u>. There are one hundred _____ in a meter. There are ten _____ in a decimeter and tem _____ in a meter.	centimeters centimeters decimeters
11. One centimeter is about .4 inches. This is about the width of your finger. One decimeter is about _____ inches. One meter is exactly _____ inches.	4 or 3.937 39.37
12. There are ten millimeters in a centimeter. This means there must be one thousand _____ in a meter. Since a centimeter is about .4 inches, a millimeter equals about _____ inches.	millimeters .04

Figure 1 continued

As can also be seen from the sample, the general technique used is quite similar to that which a good tutor might use. A good tutor rarely lectures. Instead, he conducts a well designed question and answer session using very similar rules to those which have been adopted for self-instructional materials. The success of a good tutor can be attributed to the fact that the basic procedure of getting the student to learn by means of immediately evaluating his responses to small, carefully ordered steps is superior to other methods. With only one student to work with at a time, the tutor is in an ideal position to practice this technique, which would be too difficult to attempt in a large classroom. Hence, one way of looking at a program of self-instructional materials is to visualize the possibility of recording lessons as given by a good tutor and using the scripts as a basis for writing frames. Written programs do have one advantage over such a script, however. A written program can be experimentally tried out and then modified as much as is necessary to optimize learning. A tutor, even a good one, is bound to make occasional mistakes and therefore the student will not learn quite as rapidly as he could. Furthermore, programmed materials are inexpensive and can be used over and over, while a good tutor necessarily represents an expensive form of education.

This brief introduction to the self-instructional approach has been limited to a general description of the characteristics of a program and several of the concepts underlying the technique. Although most of the evidence so far collected on the use of self-instructional materials in education is rather fragmentary, it is sufficient to suggest that the technique has considerable promise. Most of the research reports presently available represent either exploratory investigations or limited experiments designed to test the effects of a single variable. Several publications are now available which indicate the scope of recent efforts in the area of self-instruction. These include bibliographies collected by Darby (1959) and Fry, Bryan, and Rigney (1959), and books containing collected articles edited by Galanter (1959) and by Lumsdaine and Glaser (1960).

The Use of Self-Instructional Supplements in Conjunction with Televised Course Lessons

As noted earlier, the principal utility of television and films as instructional media lies in their unique capability for presenting demonstrational or illustrative material. The simultaneous presentation of moving, graphic or pictorial material and accompanying auditory explanation not only can duplicate

almost every possible live presentation of information, but can in addition, suitably magnify visual material, amplify sounds, shift readily from one type of scene to the next, and repeat or capture events which would be almost impossible to reproduce before an audience. By editing and cutting, it is also possible to select the choicest instances of a phenomenon for educational use. Because of the tremendous flexibility available with TV or film, these media will probably have not only a permanent but a growing niche in education.

Self-instructional materials, on the other hand, also have unique educational or instructional aspects. The possibilities they afford for carefully ordered sequences, inexpensive revision, thorough practice with the material, active responding, immediate feedback, and freedom from forced pacing give them great potential as a tool in the classroom. The possibility of combining these two highly complementary media for educational purposes thus deserves considerable attention.

The classroom teacher of the future is likely to employ just such a combination of media. Television and film, with their special facility for illustrating and demonstrating examples of subject matter content would be used to produce student interest and motivation and to organize complex material by means of graphic displays and sequences. Backing up the TV or film lecture would be thorough, systematic and comprehensive practice obtained through the use of self-instructional programs.

Unfortunately, many educational films and televised courses represent an attempt to achieve instructional goals more easily attained when the student is permitted to make active, overt responses. The fixed pace of televised teaching cannot most efficiently accomodate all the students viewing the course at any one time: it will cover concepts and applications too rapidly for some pupils and too slowly for others. The lecturer is too remote from the classroom to meet the needs of individual students for guidance, correction of errors, and review of material which was insufficiently grasped in the first place.

Far better instruction could probably be obtained by integrating television with self-instructional methods. One possible combination of the two media, for example, would be to introduce a given topic with a film specifically designed to cover the topic briefly. By including carefully selected material, it would serve both as a broad overview of the topic and as a means of sharpening

interest in the particular subject matter. At this point, self-instructional materials would be introduced to systematically develop a basic knowledge of the area along with a suitable proficiency in dealing with both concepts and applications. As an understanding of the material was reached, films could again be shown to illustrate specific points, demonstrate selected examples, and present specialized applications or data which would not have been comprehendable without the learning made possible by self-instruction techniques.

Some subjects, such as foreign languages or algebra, will require a great deal of tutorial assistance with only minimal use of TV or film. Other subjects, however, will require an extensive use of TV and film but very little in the way of self-instructive materials; for example, descriptive geography or dramatic arts. Most subjects, and physics as a good example, would lean heavily on both media. As the time comes when more is known about tutorial methods, it will be possible to relieve TV and film of their present dual burden and concentrate on developing the medium as a specialized tool.

General Plan of the Study

Although a limited amount of data are available concerning the magnitude of increases in achievement to be expected from programmed self-instructional materials, there is still considerable speculation as to their likely role in the classroom of the future. The investigations conducted so far are characterized by numerous shortcomings in experimental technique and applicability of results. The present study, therefore, is designed to overcome as many as possible of these criticisms. In addition, it includes the testing of several specific hypotheses regarding the use of programmed materials, and also the development of a general method for their application as supplements to televised instruction.

The overall plan of the study consists of five phases of work. These segments, which will be described in greater detail in the following sections, consist of:

1. Construction of the Programmed Materials. Several considerations were involved in deciding the content, format, and checkout procedure to be used for this experiment. Because of the lack of available data, a number of these decisions had to be made on the basis of theoretical considerations rather than experimental findings. The materials now being written therefore exemplify only one of the kinds of material which could have been produced.

They are representative of the overall technique, however, and should provide at least a firm basis for future work in the field.

2. Selection of Methods of Presentation. Considerable efforts have been devoted by various investigators to perfecting a variety of devices for displaying frames to students. Available devices afford varying degrees of control over student use of the programmed materials, and thus contribute in some measure to determining level of achievement. A second phase of this study therefore consists of a survey of the various devices available and the selection or development of suitable equipment for this project.

3. Design of the Experiment. The overall design of the experiment, including the determination of relevant controls, is especially critical in a study of this sort. This is true, primarily, because the data to be collected are to be used in two widely different ways. First, the amount of achievement attributable to the use of programmed materials must be determined. For this purpose, it is desirable to work with students who differ widely in ability, preparation, amount of instruction, and in other ways which reflect the degree to which they are representative of all students. Second, several specific hypotheses regarding the construction, presentation, or use of programmed materials will be tested. For this purpose, it would be desirable to have reasonably homogeneous groups of students. Fortunately, there are both experimental and statistical techniques which can be applied to allow the appropriate inference to be made for each purpose.

4. Conduct of the Experiment. This particular study has been oriented toward investigating the use of programmed materials as instructional supplements for televised courses. For this reason, every effort will be made to prevent the experiment from affecting other classroom routines. Very few demands will be placed on the teacher's time, either in class or in preparation of lessons. It is generally expected that, rather than interfering with the teacher's time, the use of these materials will require her to spend less of her time on classroom drills and therefore have more of an opportunity to discuss topics of special interest. The only other necessary arrangements will be the administration of four prepared examinations. Open dates have been provided in the WQED-WQEX television schedule to facilitate the scheduling of the test periods, although class time could be used.

5. Method of Evaluation. The last phase of the study consists of evaluation procedures designed to quantitatively measure the effects obtainable through use of the experimental materials. Two broad areas will be studied. First, and most important, is the effect of the self-instructional procedure on speed or amount of learning. Increased achievement would indicate the feasibility of using these materials on a large scale. The second area of change to be studied relates to motivational side-effects produced by the addition of self-instructional methods to standard courses. A greater interest in the subject matter, in breadth or depth, would also indicate the desirability of this kind of course supplement.

PROCEDURE

Considerable progress has been made in implementing the various phases of this study as described in the previous section. Details of each phase are examined in the following pages. In many cases, it was necessary to make assumptions or arbitrary decisions regarding specific points of technique or experimental design so as to limit the scope of the study. One of these decisions was to limit the subject matter to be covered to six topics covered during the second semester of the Harvey E. White Physics Course. Furthermore, it was decided that for four of these topics, Reflection of Light, Refraction of Light, Static and Current Electricity, and Electromagnetics, the supplementing materials would be developed to correspond as closely as possible to the content covered by the television films. This content can then be regarded as a standard and be used as the basis for independently developed achievement examinations. If the self-instruction programs were to be developed without this restriction, it is conceivable that the tests might be measuring differences in content rather than differences in the amount of learning promoted.

The fact that this particular course is on film was the principal reason physics was selected as the subject matter. The course also has certain characteristics which make it especially well suited as a basis for developing programmed materials. It encompasses a wide range of academic skills, the learning and applying of demonstrable facts, explanatory principles, special definitions, mathematical formulae, methods of computation, and so forth. It is also an area of considerable current interest, includes a laboratory approach, and is in no way unique as an educational subject. There is no reason to believe that results obtained on the basis of the subject matter in physics, would not be equally applicable to other, similar high school courses.

The Construction of Programmed Materials

There are, at present, two competing philosophies as to how subject-matter ought to be programmed. The first, as exemplified by the work of Crowder (1959) is an outgrowth of techniques used in testing and evaluation. The frames each include one or more paragraphs of information followed by an objective question designed to indicate whether or not the student has understood or mastered the content of the paragraph. The questions themselves are not used primarily to bring about learning but rather to provide frequent feedback as

to progress. With this approach, the learning which takes place is assumed to occur in response to the textual material as it would from any textbook. The student does not respond overtly during learning. Although he is given help in evaluating his progress, the student receives only minimal guidance to assist him in acquiring the concepts which are presented.

The second approach, developed by Skinner (1954, 1958), is an adaptation of a training technique called "successive approximations," in which the criterion response or desired final behavior is analyzed and reduced to relatively small, individual components. These response components are then rewarded as they occur. Program frames written on the basis of this approach include only a sufficient amount of text to adequately prompt the desired response to each question. It is assumed that learning can be guaranteed only through active responding on the part of the student. The questions are not to evaluate the student but to guide his responding and concomitant practice with the material. Once the correct responses are made, reward, in the form of notification that the study is correct, promotes learning. Unlike the generally objective, multiple-choice questions of Crowder (1959) and Pressey (1950), Skinner-style frames allow free responding. The student must produce the correct answer rather than select it from the alternatives provided.

The general approach to be used in this study is based on a modified form of Skinner's technique. The programs to be used are based on the notion that learning will be best facilitated by systematically guiding the development of student-constructed responses. Two changes are being made from Skinner's usual format, however. First, while Skinner generally allows only a single response per frame, the program written for this study often include multiple responses per frame. Second, while Skinner's frames are constructed so that occasional errors are likely, every effort is being made to preclude the chance of errors ever occurring in responding to the program.

Several specific variables appropriate to the construction of programs have been considered with respect to this study. These variables, as discussed in the technical literature, represent dimensions or aspects of programming which may affect the efficiency of the materials. To date, few experimental comparisons have been attempted to study these variables. For this reason, it was necessary to make decisions based on theory rather than empirical data as to the handling of these variables. Rationales for selecting the particular

values of these dimensions for this experiment are discussed at more length in the Appendix to this report.

In addition to these technical aspects of program construction, several additional aspects of the procedure deserve attention. These include the development of additional programs, methods for tryout and revision, and identification of specific rules useful in writing frames. To a large extent, the basic hypothesis of this study, that self-instructional materials used in conjunction with televised lectures will lead to measurably increased achievement, will be evaluated on the basis of four units of the second semester of high school physics. These units are Reflection of Light, Refraction of Light, Static and Current Electricity, and Electromagnetics. As previously noted, the programs written for these units will closely parallel the corresponding Harvey White lectures.

It is anticipated that a somewhat different approach will be adopted for the two additional units of self-instructional materials, on Atomics and Electronics. These two units will be prepared in such a way as to provide a limited number of students with material not now included in their course. The Atomics unit will be written so as to provide as much depth as possible into the subject matter. Instruction will involve many advanced topics usually reserved for the second or third year in college. In this way it is hoped that some information can be obtained as to the use of automated instruction for providing more material per course for selected students.

The Electronics program will demonstrate the feasibility of using automated self-instruction for laboratory or technical classwork which involves the use of equipment. The program will consist of a simple course on applied electronics. The student will be required to furnish a large number of manipulative as well as verbal responses. Reinforcement for the manipulative responses will be provided by feedback from equipment which will be furnished to the student along with the program. It is planned that these two advanced programs will be made available to students on a voluntary basis.

One of the unique features of programmed material is that it can be systematically revised on the basis of information collected during its use. A lecture or textbook which fails to promote optimal learning is much more difficult to improve once it has been prepared. A program, on the other hand, can be continually refined during use by determining particularly deficient

sections. Unlike a textbook, for instance, the program has each small unit of material in carefully delineated form. Wherever several students fail to respond correctly on any one frame, educators preparing the program are in a position to identify the particular point of difficulty and can add or modify material at that point so that errors are no longer made. An author of a textbook is not in a position to obtain this information. He may, on the basis of an achievement test, discover that his readers have failed to comprehend the information included under a certain topic. He then knows the topic must be revised, yet he has no knowledge as to what aspects of the often large section in the text are causing the difficulty. It is, therefore, impossible for him to use the information he can obtain to assist him in making revisions. Data from tryouts of programmed material indicate the specific concept which is creating the difficulty. That frame or group of frames can then be revised without having to modify the entire section.

A very important procedure during the construction of tutorial materials, then, is obtaining evidence on the effectiveness of each sequence as it is developed. Revising the program is as important as writing the frames in the first place. It is expected that, for programs developed in this study, at least two individual tryouts and one small group tryout will be conducted before the frames are reproduced in final form. Revisions will be made after each tryout and, if the number of programming errors warrant it, additional tryouts will be added for a particular section.

One barrier standing in the way of more widespread applications of the self-instruction technique is that programming is currently much more of an art than a science. There are no clear-cut rules available for converting subject matter to programmed form. For the present, it is possible to do without such rules or guides by depending on the writer's ingenuity and the amount of pretesting possible.

It is quite evident that the automated instructional technique cannot forever depend on such vague methods as these. One specific contribution of this study will therefore consist of an attempt to develop approximations of programming principles. These will be produced by means of sorting frames into provisional categories in terms of such factors as content, style, etc. Since these categories will be formulated after the frames are written, they will not necessarily form a systematic guide for future work. The categories will

provide some indication as to the latitude to be found in a large collection of frames, however, and will serve as a basis for developing a tentative taxonomy.

The Selection of Methods of Presentation

One of the more interesting aspects of self-instructional research concerns the design and use of devices to simplify the presentation of material. An important attribute of self-instructional materials is that their presentation can be fully automated. The design of the present study provides the opportunity to compare the relative effectiveness of differently instrumented methods of presentation. The data obtainable will not provide full information concerning optimal design characteristics. However, they should at least provide some information on the important question of the value of an automatic means for assessing the correctness of student responses.

In general, the devices which have thus far been developed or produced probably represent what someday will be regarded as only approximations of optimal machines. To a large degree, current designs reflect various attempts to solve specific problems faced by a particular programmer. Descriptions of many of the resulting devices can be found in several reports, such as those by Lumsdaine (1959 a, b), Briggs (1959), Fry, Bryan and Rigney (1959). To date, there is little research evidence available upon which to determine the particular device or method best suited for use in a study such as this one. The selection of a method of presentation must therefore be done arbitrarily on theoretical grounds.

As described more fully in the Appendix to this report, there are four aspects of programmed instruction which could be mechanized or automated. The first of these is the presentation of material to the student. Devices already developed or now under development which incorporate this feature include examples of several distinct approaches. Among these are printed pages, printed paper tape, cards, and microfilm in strip, slide, and microcard form. The selection of any one of these methods depends on the flexibility desired, the amount of control wanted, and the economic limitations involved. For most purposes, film presentation should prove to be more satisfactory in all these respects than other methods. The ease with which changes can be made and the lower per frame cost of reproduction, once low-cost projectors are acquired, suggest that film will ultimately be the most satisfactory medium.

The second aspect of programmed instruction which could be automated is the process by which the student's response is registered and recorded. For constructed responses, at least, the only response-recording methods now available are to record the student's oral responses, to have him write them out on paper tape, an answer pad, or the book itself, or to register them mechanically by means of a keyboard or similar device. The importance of a permanent record of student responses depends considerably on the extent to which future revisions of the program are expected.

The third aspect is that of response evaluation. This is likely to be the most critical of the four possible applications of automation in programmed instruction. At least with respect to constructed responses, there are only two distinct possibilities. Either the device evaluates the student response automatically, or the student is given this responsibility himself as aided by a correct answer made visible to him. The latter system has at least two potentially important disadvantages: the student may easily make errors and, as Edwards (1956), Lumsdaine (1959a) and others have pointed out, this necessitates furnishing the correct answer to the student when his attempt was incorrect.

The fourth aspect is that of reward or reinforcement following a correct response. Many programmers have so far assumed that the correct answer itself is a satisfactory reward. Further research in this area is required, however, to determine if some other form of reinforcement, such as points furnished by a teaching machine device, might lead to even more rapid learning.

At present there are few research findings to assist in the selection of a teaching machine. For this reason, it is hoped that some information can be obtained on the use of devices in the present study. In order to study the magnitude of device-produced differences, it is planned that a comparison will be made between at least two kinds of devices. Although this will not permit a rigorous evaluation of specific design features, it will provide data concerning the range of differences which could be expected. Two kinds of devices are being considered for this study. The first will be selected from available devices which involve relatively little in the way of production costs or automation. The second kind of device will be one in which rather extensive automation, within reasonable economic limits, is used. If possible, this second device will include some sort of automated response-evaluation feature.

The Design of the Experiment

It would be desirable to explore as many of the issues concerning programming as possible in this study. However, investigating many variables at one time detracts, in terms of grouping of subjects and simplicity of design, from efforts which ought to be devoted to basic issues. For this study, one hypothesis is considered of primary importance. This is the basic question of whether automated teaching does contribute significantly to achievement on representative subject matter for a typical high school population.

Evidence thus far available has generally been limited to small-scale pilot studies. Few of these clearly demonstrate the efficiency with which present day understanding of the learning process allows us to improve the amount that can be learned in a given time period. In general, these experiments have utilized only a few subjects, often representing a very selected segment of the school population, such as college students or preschool children. This study, by contrast, will collect data from a large sample of students, expected to be representative of most high school pupils. They will be attending a number of different schools in several school districts. They will represent a wide spectrum of ability and interest levels.

Many of the previous studies have, furthermore, been quite restricted in their subject matter. For the present study, a fairly typical high school subject, physics, has been chosen. In the basic experiment, approximately one-third of the year-long course will be covered. All students will be exposed to the same overall content through daily telecasts of filmed physics lectures, but the various classes, having different teachers and textbooks, will study the subject in slightly different ways. This will increase the potential of the results for application to other situations.

One further control will be employed to regulate the source of achievement. In using the programmed materials some students may very likely spend extra time on their studies. To control this factor, some of the students not given programmed materials will be given practice exercises similar to those often found in review workbooks.

These three factors--a large, unselected sample of subjects, typical high school subject matter with controlled exposure to content, and balanced study time--will eliminate much of the inconclusiveness now surrounding teaching-machine studies.

The two principal treatments in the experiment are the experimental condition (E) and the major control condition (C). Condition C consists of exposure to the televised lectures with no special provision for supplementary instruction beyond that normally offered through regular classroom instruction practices--i.e., teacher lectures and other help, classroom recitation, and a text. Condition E is parallel to condition C except that the students are, in addition, furnished with the supplementary programmed instruction. To control for variations in student ability and classroom practices, two groups of students will be alternated between these two conditions. In this way, data will be available on the achievement of each student under both conditions. In the table, these two groups are identified as Groups I and II.

EXPERIMENTAL DESIGN

Unit \ Group	I	II	III	IV	V
Electricity 1	E	C	C	E	W
Electricity 2	C	E	C	E	W
Light 1	E	C	C	E	W
Light 2	C	E	C	E	W

Although this arrangement will control such variables as classroom and individual differences, it does not control possible long-term effects due to experience with self-instructional materials. Thus, a student who has had some initial experience with the way programmed materials are organized, may show significant improvement in his later work, even if he is no longer supplied with self-instructional materials. This may occur because he is now better able to organize new material for himself in the same way. To provide a standard with which to test this hypothesis, Group III will continue under C conditions throughout the study.

It is also desirable to make provision for observing possible cumulative effects resulting from the sustained use of programmed materials. This will be accomplished by observing the performance of Group IV, which will have E conditions throughout the study.

At present it is difficult to anticipate with much assurance the overall effects of self-instructional materials on study habits. Accordingly, as noted earlier, an additional feature of the study will be the use of conventional workbooks by some of the students in order to afford some check on the amount

of time students spend in preparation and study. These students will be furnished with a set of rather traditional workbook materials, which have been prepared by the Extension Division of the University of Wisconsin to accompany the Harvey White physics course. These materials differ from those being constructed for this study in several ways. They do not employ small steps, complete sequencing, or immediate feedback. Students receiving the conventional workbooks are represented by Group V in the experimental design. Students in the group will be provided with workbook materials (W) for the length of the principal part of the study.

A supplementary condition not represented in the table is concerned with the effects of using relatively elaborate machines instead of the simpler devices to be utilized in the major experimental condition (E). This additional experimental condition will be introduced only for a relatively small number of students. Because of the extensive preparation required to adapt programmed materials for use in the more complex apparatus, this will be done only for one of the later units of the course.

To the extent possible, additional programmed materials on Atomics and Electronics will be provided on an elective basis to as many students as feasible. Since in this case the content to be covered goes considerably beyond the scope of the course, use of these optional materials would afford a demonstration of a further application of automated instruction.

The Conduct of the Experiment

As part of this study, a new kind of teaching material is going to be brought into the classroom. The material will be employed over relatively long periods of time and is expected to have a fairly pronounced effect on the achievement of students who use them. To insure a fair and unbiased evaluation of the data obtained from the study, it has been necessary to arrange for a certain amount of cooperation from the administrative and teaching staffs of participating high schools. Each of the six groups to be used in the study must be treated according to the conditions set forth in the previous section. Any deviation from this pattern would reduce the applicability of results and therefore eliminate much of the meaning to be derived from the findings.

This experiment is devoted solely to increasing knowledge as to how learning takes place and how achievement can be enhanced through the use of self-instructional techniques. The purpose of the study is not to evaluate

current teaching methods, compare teachers or textbooks, or examine the content of physics courses. Instead, the objective is to shed some light on critical aspects of the learning process and thereby advance the understanding of educational technology.

As noted earlier, one of the requirements of the study is the sampling of as wide a range as possible of high school physics classes. If the time comes when supplementary programmed materials become sufficiently well-developed to incorporate them into ongoing educational programs, it is likely that as much variability will exist among classes and methods of classroom instruction as exists today. Studying the effects of self-instructional materials in a homogeneous situation would severly limit the usefulness of the experiment with respect to extrapolations of the data. For this reason, the participating teachers will be allowed as much flexibility as possible in the way materials will be utilized, and will be encouraged to continue with their usual teaching practices throughout the length of the study. Several aspects of the study which relate to both the conduct of the class and the conduct of the study are identified more explicitly below.

First, while it is not necessary that every student watch every day's telecast, the class must be able to watch nearly all of them. Only classes which have been following this practice during the current school year will participate in the study. The teachers of both experimental and control groups will be asked to keep a daily record of whether or not the class watched a particular lesson, whether the quality of reception was adequate or not, and which students were absent from school. Special school assemblies, optional holidays, or an erratic television set will randomly force individual classes to miss a given lesson, and illness or weather conditions may prevent the attendance of individual students on any given day. Conditions such as these are common to all schools, however, and will be accepted for this study as typical or representative of the difficulties faced every day in secondary education.

The second aspect of the study of special importance to cooperating teachers is the distribution of the supplementary materials to students and the assignment of work to be accomplished with them. Everything possible will be done to make this task as simple as possible in order to create minimum interference with the teachers' planned use of class time. As noted earlier, the materials will have been organized so that they can be distributed and

collected with ease. They will have been pretested so that the teacher will not find it necessary to accompany their distribution with lengthy explanations as to what is to be done routinely or when the unexpected occurs. To further assist with the initial distribution of the programmed materials to a particular class, a brief instructional motion picture is being prepared on the use of the materials. The motion picture will be shown to all students in the experimental groups.

With respect to the conditions of the study, the only requirement concerning the materials is that the students be given reasonable opportunity to work with them. Whether this is done during class time or assigned as homework is largely up to the individual teacher. Since individual students go through the materials at somewhat varying rates, it is expected that the teacher might best plan to have the students accomplish the larger part of their work on their own time. It is expected that relatively little urging will be required on the teacher's part to develop an interest in studying physics by means of these materials. Students who "give up" on the materials will be relatively rare and since part of the role of self-instructional materials is to provide a suitable program of instruction for all students, it will be considered the program's fault if large numbers of students fail to maintain an active interest in them.

Of more immediate concern to the teachers is the direct role they will play in the conduct of the study. It is planned that, in general, the teacher will be asked to do no more with respect to the supplementing materials than distribute them to her classes as scheduled and then collect the answer forms periodically. The answers should not be graded by the teacher. In fact, the teacher will be asked not to even inspect the answers since knowledge of the students' progress will tend to affect topics covered in the classroom. Beyond this, it is expected that teachers will conduct their classes very much as they would if the study were not in progress. The teachers will be free to use their choice of textbooks, lectures, and special materials. They will be asked, however, not to use the University of Wisconsin Study materials unless their class is scheduled to use them. Where these materials are called for, they will be provided at no cost to the students or schools.

The few classes employing the more complex teaching machine device will have to work in school. It may not be possible to provide more than about one device for four to six pupils, so that special arrangements may have to

be made with respect to their use.

The teachers will be asked to schedule seven periods during the semester for the special achievement examinations which will be given. These examinations, described more fully in the following section, will be given at the end of each major unit and at the end of the course. Taking these examinations will not cause students to miss any of the regular televised lessons, because they can be given only on days when repeat films have been scheduled. This arrangement has been made possible with the cooperation of educational television stations WQED and WQEX. The teacher of each class will be furnished with a roster of the scores of the students in the class as soon as these are available. However, since some delay is expected in the scoring and processing of these tests, it is expected that the teachers will use their own classroom examinations for providing semester grades for the course.

Use of the proposed advanced programs, that is, the self-instructional materials in atomics and electronics, will be optional with students. As many students as possible will be provided with a set of materials in one or both of these areas. In both cases, these will cover much more material than is ordinarily given in a high school course, and it is expected that all the work the students do with these advanced materials will be done at home.

The Method of Evaluation

The primary objective of this study is to determine the extent to which tutorial self-instructional media can improve achievement. The evaluation will, therefore, be based principally on objectively-scored physics achievement tests. In addition, it may be possible to demonstrate some changes produced by this method of study on attitudes toward school and the subject matter. Such information would be helpful in planning future studies involving the use of similar materials and in setting up procedures to make use of new programmed courses as they are developed.

Two types of examinations will be given. The first type comprises six separate achievement tests based on the content of the Harvey White physics lectures used in this study. One examination has been assembled for each of the six units to be programmed; electromotives, electromagnetics, reflection, refraction, atomics, and electronics. Each test will consist of approximately forty multiple-choice items.

So as to prevent any possible contamination of the test items, in terms of selecting or constructing them in such a way as to favor the experimental group, it was necessary to have the tests developed by individuals who were not directly involved in the study and who did not have access to the programmed materials. The Test Development Division of Educational Testing Service is cooperating in this study by assembling the necessary achievement test items and reproducing the examinations. As guides, they have been furnished with copies of the scripts of the relevant White telecasts, and are using these as the basis for deciding the appropriateness of each potential item. Their only limiting instructions have been to ignore purely historical material included in the lectures, which has also been excluded from the content of the self-instructional materials. No one on the project staff will see these items until the supplements are completed.

The two achievement tests on electricity will be administered to the control and experimental groups at the end of these two units. Since the examination on electromotives will be given several weeks after that material was covered in class, the results will combine information from both immediate and delayed testing. The examinations on light and on atomics and electronics will likewise be given following the completion of each pair of units. Along with the experimental and control subjects, several additional high-school physics classes will be given the examinations. The data obtained from these groups will be used to conduct item analysis and reliability studies on the tests themselves.

The second type of examination will be given at the end of the school semester. This will be a standard College Entrance Examination Board (CEEB) Physics Examination, also furnished by Educational Testing Service. This test will be analyzed in terms of the items appropriate to each of the units covered by this study. The results of this test will provide some indication as to the retention of the material. They will also indicate whether any increased achievement in unrelated sections of the course results from using the experimental materials.

In addition to the examinations, a brief scale of attitudes developed especially for this study will be administered. The scale will consist of self-report statements concerning study habits, course preferences, future educational goals, and other aspects of education. The questions will also indicate the students' feelings toward self-instructional materials.

SUMMARY

This study will assess the value of self-instructional materials used to supplement a series of televised lessons in physics. These materials were developed especially for the purposes of this study. They represent a new technique of instruction that has considerable promise for the future of education.

This study does not proport to answer all the many questions raised by recent developments in automated instruction. It does, however, provide a basis for collecting essential data on the potential role of self-instructional materials. By using large groups of representative students and extensive blocks of materials, the study will contribute to the value of future applications and research.

APPENDIX

Technical Considerations Involved

in the

Construction and Presentation of Programmed Materials

Construction and Presentation of Programmed Materials

The relatively brief history of teaching-machine research is characterized by the very large number of suggestions offered as to methods for programming material and presenting the finished sequence to the student. Unfortunately, there is only a limited amount of published literature on the subject and, of this amount, only a small fraction has appeared in professional journals and other accessible sources. This report would therefore be incomplete without a brief review of some of the more pertinent problems now being investigated and discussed by those doing research in this area.

It is important, for a study such as the one described in this report, to state the assumptions made by the project investigators in preparing materials and selecting devices for use in the study. As noted previously, the programmed materials being written for this study are designed to be as representative as possible of the aims set forth by those who began the initial research in this area. Clear guidelines are not available, however. For this reason, it has been necessary to develop an appropriate technology and approach to programming as part of this study. While it is not possible to recreate all the problems that have been dealt with thus far, some of the more critical ones will be at least mentioned.

To begin with, some frame of reference is necessary as a basis for developing programmed materials. The theoretical framework used by most researchers working with programmed self-instruction consists of generalizations developed from the knowledge psychology has been able to accumulate about the learning process. The large number of rules which have been discovered by behavioral scientists for enhancing the speed and thoroughness of learning cannot be applied directly to educational situations, however. Thus far, it has only been possible to adapt a few of these rules to a form suitable for use of a program writer. For instance, it is felt that proper sequencing, minimal delay in feedback, the prevention of errors, and requiring responses in context are all goals which should be incorporated into programs. Techniques for actually implementing or carrying out these rules are only now beginning to evolve.

It is therefore not surprising that the form and characteristics of current programs depend heavily on the skill and ingenuity of the writer. As is also true of other educational methods, programmed instruction is largely the art of translating technical information into the form in which it is most easily learned by a student. But just as it is possible to describe useful techniques which have evolved in other forms of instruction, it is possible to generate useful guides for programming by examining some of the procedures which are being used. While rules identified in this fashion largely represent working assumptions found helpful by the programmer, they do illustrate various aspects of the approach used to create a program.

Several general rules for programming have been developed as part of this project. By and large, they are hypotheses as to suitable techniques rather than empirical findings, and have been used accordingly in this study. Some of these more general working guides are:

1. The student is not assumed to have learned anything about the subject matter except for those responses which he has made correctly in the proper context. Fully active participation by the student does not, of course, insure learning. But it does enable us to follow his progress, supply additional information and practice as necessary, and provide reward or reinforcement following the occurance of those responses we wish to encourage.

2. It follows from the first point that "lecturing" in the course of the program is to be discouraged. While some learning often appears to take place following only passive exposure to new material, this more than likely represents our inability to observe covert behavior as it does true passive learning.

3. A third general rule is that abundant practice, even if redundant for some students, is better than too few repetitions of the response. Potential monotony of large numbers of repetitions can be offset by variations in the context. This has the additional advantage of producing desirable amounts of generalization.

4. The fourth general rule is that potential errors and misunderstandings must be anticipated and prevented. This is often more easily done on an empirical basis than a theoretical one. Students trying the program make surprisingly good editors. While they cannot correct errors in the program, the frequency of their incorrect responses indicates the sections of the program that need correcting. Once a student has made an incorrect response, it is then more difficult to get him to make the correct one than if he had not made an error.

5. The fifth general rule is quite vague but in part summarizes the first four, and, as a guide for writing a program, may be helpful. This rule is that it is not how much the student has been exposed to which is important, but how much he has learned.

While these guidelines are perhaps too general to be of much use to the new program writer, they do reflect some of the thinking which has directed the writing of materials for this particular project. It is expected that a number of more specific guides will be developed at a later time by going back over the materials written for this study.

From a technical standpoint, there are also a number of guidelines that can be developed to characterize programmed materials. These represent points of view attributable to specific program writers rather than to the philosophy of self-instructional devices. Each of the following technical aspects of programming was considered during the writing of the programs used in this study. These variables represent diminsions of programming which may affect the efficiency of the materials. In each case, the principal characteristics of each alternative are briefly described, and the alternative selected for use in this study is identified.

1. Cueing. Two principal cueing methods have been suggested for evoking low probability constructed responses. These are semantic or contextual prompting and prompting by physical stimulus reduction. The former is the utilization of verbal cues in the text to make an otherwise unlikely response

occur. Compare, for instance, the three frames in Figure A. The first of these provides minimal assistance, the second somewhat more, but the third will likely evoke the correct response even from someone quite unfamiliar with the measurement of temperature. Other forms of prompting are based on the use of particular word frames, grammatical construction, figures, rhymes, and so forth.

a) Along with Fahrenheit and centigrade, Kelvin is a _____.

b) Fahrenheit and centigrade are scales of temperature, Kelvin is a _____.

c) Fahrenheit and centigrade are scales of temperature, Kelvin is <u>also</u> a _____.

Figure A

The other general method of prompting depends on physical variation of visual (or auditory) cues. Figure B illustrates one form that has been suggested. Although no data are available on the relative efficiency of each approach, a decision was made to use semantic prompting, partly because lesser difficulties in reproduction of materials were anticipated with this method. In both cases, fading or vanishing--i.e., diminishing the strength of cues--is used as learning progresses.

a) Kelvin is a XXXXX XX XXXXXXXXXX.

b) Kelvin is a XcXXX Xf XXXpXXaXXrX.

c) Kelvin is a scXXX Xf XXmpXXatXrX.

d) Kelvin is a scaXX of XempXXaturX.

Figure B

2. <u>Pacing</u>. This refers to the rate at which responses are to be made. If <u>external pacing</u> is used, some control is exerted over the speed at which the student works. This is probably necessary where speed itself is an important component of the skill being learned, as would be the case with typing or shorthand. For academic material, however, external pacing may "lose" the slower students or possibly bore the brighter students. For this reason it was decided to use <u>self-pacing</u> in this study.

3. <u>Size of step</u>. This variable in programming refers to the scope of information or concepts to be presented in each frame. Although any one frame is most often used to guide the learning of only one point, the magnitude or depth of the point can vary considerably. As a general principle, it seems

that more satisfactory results will be obtained when the size of step is small enough so that any potential user will be capable of fully mastering the material, that is, when step difficulty is minimal (Skinner, 1958; Evans, Glaser and Homme, 1959). Rather than defining 'difficulty' in terms of intrinsic characteristics of the frame, it is more functional to use it to mean the proportion of the population, for which the program is intended, who make an error on that frame. A program which is too difficult, of course, will result in hardly any learning. The question is more complex, however, when considering frames which are too easy. As yet, no information is available to answer the question as to what happens when a student gets every frame correct. On the one hand, Skinner's studies of continuous versus intermittent reinforcement would suggest that occasional errors would strengthen the general response of responding to programmed material or at least prevent rapid extinction as the result of a few successive errors. On the other hand, Guthrie's view of learning would suggest that each error would necessitate retraining. One compromise, of course, would be to insure correct answers by means of sufficiently easy frames, but by one means or another, reinforce on an intermittent basis. Further research in this area is required. The present study will use "easy" frames which are apt to be the safer of the two alternatives.

4. Frequency of repitition. This and the following aspect of programming are both related to size of step and, in practice, all three must be considered together. As the number of times a student is required to repeat a particular response is increased, it becomes more likely that a difficult concept will be mastered and that it will be retained for a longer period of time. In practice, the number of repetitions can be counted in two ways: the number of successive evocations of the same response, using less and less cueing each time, and the number of successive evocations of the same response, using different examples each time. At the present time, an optimum frequency of repetition is very difficult to determine because it is so highly dependent on the particular population to be used, the subject matter being taught, and the skill with which the frames were written.

5. Initial difficulty level. Two questions frequently encountered during the preparation of a program are: How strong can relevant responses already in the students' repertoire be assumed to be? and, How much preparation for the introduction of a new concept is desirable? To answer these questions, it is necessary to be fairly definitive as to the goals of the program. Clearly, a great deal more preparation would be required to teach high school physics to the average sixth grader than the average tenth grader. The tenth grade student can be assumed, in most cases, to already be familiar with a few concepts in algebra, for instance, and it is therefore possible to omit portions of introductory algebra from a program designed to be useful at this level. For this study, it has been assumed that every student now enrolled in area physics classes is capable of mastering the material in the course. Sufficient preparation will therefore be given to promote satisfactory achievement in even the least prepared of these students.

6. Branching. The problem of what to do with the very bright and very dull student has been with education for many years. Boring the bright ones or losing the dull ones is a side effect resulting from trying to teach thirty or more pupils at the same time. To combat potential difficulties, educators discovered it was possible to give special work to those mastering the regular

assignment very quickly, and special help to those unable to keep up with the class. This procedure, adapted for automated teaching, is called branching. The student who fails to adequately comprehend a specific section is provided with a special sequence which covers the same material in greater detail. In this way, the bright student can proceed as rapidly as possible while the dull student is given additional assistance in areas of difficulty. It can be hypothesized, however, that a bright student will not be bored by easy material, providing he is free to go through it at a rapid rate. By making this assumption and including all the necessary material in the standard program, the administrative complexities of branching are eliminated. This is what has been done here.

5. Bypass. This term refers to an alternate procedure to branching; that is, where the standard program is made up of many small steps, the bright student is to bypass review or repetitive segments of the program which are not necessary to his mastery of the material. In general, the same comments applicable to branching are applicable to the bypass procedure. Bypassing will not be used in the present study.

6. Scoring. Whether or not to score responses to frames is another question on which there is some disagreement. Scoring here means a particular kind of feedback, that is, computing the number or proportion of correct responses so as to indicate to the student how well he is doing. An analysis of responses for purposes of improving the program is usually done routinely, regardless of whether qualitative feedback is given to the student. One advantage of programming is that it can provide the student with a non-aversive learning situation. Scoring is not compatable with this goal since a low score would be aversive to the very students who most need a non-punitive learning experience. In addition, the utility of scoring is questionable in non-branching programs, since it leads to no special change in what the student is to do. This kind of scoring will not be used in this investigation.

7. Drop-out. The program for college psychology developed by B. F. Skinner and J. G. Holland utilizes both scoring and drop-out. As the student proceeds through each unit of the course, his responses to individual frames are scored. On completion of the unit, he is to begin the unit over again, but omit those frames on which he was previously correct. This drop-out technique is repeated over and over again until the student has correctly responded to each stimulus frame. While this procedure insured that the student will have provided the correct answer once to each frame, it entails the aversive effects of scoring. It would seem to be a more effective goal to try to devise frames that would produce no incorrect answers at all.

8. Enrichment. The problem of what to teach is a very important one for programmed material. Ideally, it is necessary to first have some agreement as to which specific principles, concepts, methods or details of the subject matter should be included in a program and then write frames accordingly. Until agreement is reached, however, there will be some marginally important information which would necessitate many additional frames if included. It has been suggested that this kind of material be handled through "enrichment"--that is, incorporating incidental information which the student reads but which is not essential to his making the required overt response. In a textbook, some information is presented as background in an incidental way, such as the

name of a contributor to the field, the date of a particular development or some unusually interesting application of a discovery. Generally, such information is presented more for its entertainment, interest, or motivating properties rather than for its own sake. This form of enrichment can also be included in a program in the same way. The "b" examples in Figure C illustrate two uses of enrichment in a stimulus frame and one use of this method in a response frame.

1a. Semi-conductors are substances which have less free electrons than conductors but enough to allow _____.

1b. Semi-conductors, such as germanium and silicon, are substances which have less free electrons than conductors but enough to allow _____.

2a. Static electricity is demonstrated when an amber rod, rubbed with fur, will _____.

2b. Static electricity was first demonstrated by the Greek philosopher Thales, twenty-five centuries ago. He demonstrated that an amber rod, rubbed with fur, will _____.

3. (A meniscus lens has one convex surface and one _____ surface.)

3a. Concave.

3b. Concave; meniscus lenses are frequently used in eyeglasses.

Figure C

9. Review. It is likely that programs developed for automated teaching will contribute a great deal to our understanding of the learning process. This is particularly true in terms of review and the problems of retention. How often to schedule review, and what review should consist of, are problems to be decided only after considerable research has been completed. For this study, review frames will be developed for use both during learning and just before the examination. Most of the final review materials will consist of an easy frame on the principle, followed by a frame requiring the student to state the principle, followed by a frame requiring the use of the principle in some typical application.

Another major technical problem is that of a method for efficiently presenting the completed frames to the student. That this process can be carried out mechanically is one of the most impressive features of programmed instruction, and has led to the technique being popularly referred to in terms of "Teaching Machines." While several systems and machines have been devised for this purpose (see descriptions by Fry, Bryan, and Rigney, 1959, and by Lumsdaine, 1959a, 1959b), none of these are capable of meeting the needs of all types of programs, formats or uses, and the experimentor or educator is still faced with the problem of selecting, adapting, or even developing appropriate devices for his own use.

Broadly speaking, there are two major methods for presenting frames to the student. The first includes the machineless procedures, those which do not involve the use of any mechanical device into which the program is inserted. Perhaps the simplest of these is no more than a stack of cards with the question printed on one side and the answer on the other. Cards are difficult to handle, however, and can be easily dropped and gotten out of order. Less flexible but more portable is a format called a "Programmed Text." This is a bound book containing three to five frames to a page. The question is on one page and the answer is on the following page so that it is not visible while the student is answering the question. The second major method depends on an electrically or mechanically operated device and presents frames by means of film, paper tape, or paper disks.

It has been felt that some form of mechanical presentation affords greater control over the learning situation, by preventing peeking at the answers or skipping questions, and may provide greater motivation. The devices thus far developed for this purpose range from very simple shields to microfilm projectors which have some built-in mechanism for evaluating the student's responses automatically, and thus eliminate errors resulting from the student's acting as "comparator."

Since one goal of the study described in this report is the collection of empirical information as to the relative efficiency of these two major categories, several aspects of the presentation questions were examined carefully. To accent the more important criteria involved in designing or selecting a teaching machine, an analysis was made of what occurs, or should occur, when the student interacts with a self-instructional program.

First, the frames must be presented to the student both individually and in a prearranged order. Several methods, including those described above, are available for achieving this goal. The frames may be bound in a book in such a way that exposure to all but the one frame being responded to is controlled or eliminated. Problems of the student "looking ahead," skipping difficult frames without responding, or being confused by having several frames exposed at one time cannot presently be eliminated in this manner, although various ideas have been advanced for reducing the magnitude of the problem by means of specially arranged books and other means. The assumption must still be made however, that with proper instruction, the student will use the book of material as its author intended it to be used. Better solutions are possible when the frames are "locked" into a mechanical device which does present only one frame at a time. This is made possible with devices incorporating stacks of cards, long paper tapes, or microfilm which presents stimuli to the student through a

window or screen. It is likely that a film-presenting device ultimately will prove to be most acceptable providing the problems of cost of the device and its portability are solved. As a general rule, once the machine is acquired, the cost of filmed programs will probably be less per frame than even the cost of programs published in book form.

The next step in the automated teaching sequence, after the frame is presented, is the making of a response of the student. (Here, only constructed responses will be considered.) He may make the response covertly, verbally, written out, or even typewritten by means of mechanical assistance. One large advantage seems to be afforded by recorded responses; they may be later scored and analyzed to provide information about the student's progress or about weak points in the program. While machine recording is difficult to design and produce inexpensively, and often depends on subject pretraining, as would be necessary if a typewriter keyboard were used, it does have the advantage of potentially forcing the student to make every required response and therefore not omit or skip over very easy or very difficult frames. At least one design, Skinner's disk machine, offers some compromise between this requirement and the ease of a written response. Answers are written on a paper tape which is fed beneath a slot in the equipment. Each time the student advances to the next frame the tape is moved and, even though the device does not automatically prevent the skipping of frames, the blank spot in the tape records the fact that this was done.

The third step is the evaluation of the response as to its correctness. At this point, the differences between teaching machine methods becomes most pronounced. If the student can be relied upon to evaluate his own response by comparing it with a correct response displayed by the device, the problem is relatively simple. But, this specific assumption is hard to make with respect to the student who does make errors as he proceeds through the program. Figure D illustrates three possible kinds of errors, all caused, in part, by poorly written frames. In the first example, either "reflection" or "refraction" could be considered the correct answer by a student who had insufficient understanding of the two phenomena. The student answering "refraction" could feel the programmer made an error, and that, while not given as an answer, "refraction" was nevertheless correct. The second example demonstrates the opposite interpretation by a student. If he responded "bent" rather than the keyed answer "reflected," he might consider himself to be in error even though he was correct. The third frame is the most difficult of all to handle. Long, constructed responses are highly desirable in a program, but entail serious evaluation problems. Very few students will compose their answers so that they correspond identically to the key. Is the student then correct or incorrect? For example, one student may answer "reflection is the bending of light." Another may say "refraction is the reversal of light rays as they strike a smooth surface." Still another may respond "reflection is the bending of light rays as they strike the surface of an object which is caused by the fact that light strikes the surfact at an angle." All three answers are incorrect, but this is not likely to be noted by a student who makes an incorrect response in the first place.

1. The bending of light as it strikes the surfact of an opaque medium is called _____.	reflection
2. When light strikes a surface it is often _____ and hence changes direction.	reflected
3. What is reflection?	reflection is the bending of light rays striking the surface of an object

Figure D

Properly constructed and tested frames can do a great deal to eliminate these problems, but using the student as a comparator is a weak point of current practices in automated teaching. Automatic devices have been designed to prevent some of the error. By typing out the correct answer, much of the judgment factor is eliminated since the machine can then electrically or mechanically compare the student's response with the criterion. This system is only suitable, at present, for short answers and when the student can be assumed to spell his answer correctly. In most current designs of this type, only one answer is allowed so synonyms are counted as errors. As a possible solution, it has been suggested that the student may first compose an answer and then compare it with several standards, selecting the one most closely resembling his composed response which he then reports to the device. By reducing the machine task to evaluating only a choice of maybe three alternatives, the evaluation is made quite simple. This merely extends the possible judgments the student could make to include more possibilities, however. Instead of evaluating his response as to "correct" or "incorrect," he can sort it into a few more categories. Instead of comparing his response with the answer, he compares it with the three or four alternatives given. In both cases, he is still responsible for his own comparisons.

The last step is reinforcement, feedback or reward for being correct. Thus far, most programmers have felt that being correct will itself be a sufficient reinforcement to the student. While this seems to be the case with respect to the short programs developed so far, it may be that additional forms of reinforcement must be provided to maintain responding at high strength. Aside from recognizing the need for reinforcement to be immediate to be effective, there has been little research into this particular area to this time, although mechanical devices could be easily developed to provide points, flashing lights, and so forth. Such devices would also allow the possibility of experimenting with various intermittent reinforcement schedules.

These four steps, then, comprise the possible areas in which automation may be employed with programs. Whether or not a particular design feature is worthwhile will depend on the criteria used to evaluate all teaching practices; does it produce superior achievement and does it produce this achievement economically? It may be possible, in addition, that devices have an intrinsic motivational quality, especially for children.

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